JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES
VOL. VII OCTOBER 19, 1917 No. 17

PHYSICS.—*The resonance and ionization potentials for electrons in sodium vapor.* JOHN T. TATE and PAUL D. FOOTE, Bureau of Standards.

When electrons are accelerated through mercury or cadmium vapor two distinct types of inelastic impact have been observed to take place. The first of these occurs at the experimentally observed potentials of 4.90 volts for mercury[1] and 3.88 volts for cadmium[2] and is accompanied by the radiation of light of a single wave length, 2536.72 Å for mercury[3] and 3260.17 Å for cadmium.[4] This radiation is not the result of a recombination with the atom of an electron removed by the impact but is to be regarded as due to an agitation of the electrons bound in the atom.[5] The large transfer of energy from the moving electron to the atom may be explained if we assume that at these critical velocities the time of interaction between electron and atom bears a simple relation to the natural period of vibration of one of the electrons bound in the atom. Under these conditions the electron may be said to have a resonance velocity characteristic of the vapor through which it is moving. The resonance velocity may be calculated theoretically[6] from the frequency, $\nu$, of the radiation emitted, by making use of the relation

$$h\nu = eV$$

where $h$ is Planck's element of action (here assumed to be

[1] FRANCK and HERTZ. Verh. d. D. Phys. Ges., **16**: 457–467. 1914.
[2] TATE and FOOTE. Bull. Bur. Stds. (In press.)
[3] FRANCK and HERTZ. Verh. d. D. Phys. Ges., **16**: 512–517. 1914.
[4] McLENNAN and HENDERSON. Proc. Roy. Soc. Lond., **91**: 485–491. 1915.
[5] TATE. Phys. Rev, **7**: 686–687. 1916. TATE and FOOTE. Idem, **10**: 81. 1917.
[6] McLENNAN and HENDERSON. Loc. cit.

$6.56 \times 10^{-27}$ erg sec.),[7] $e$ the electronic charge, and $V$ the potential necessary to give the electrons the resonating velocity. The

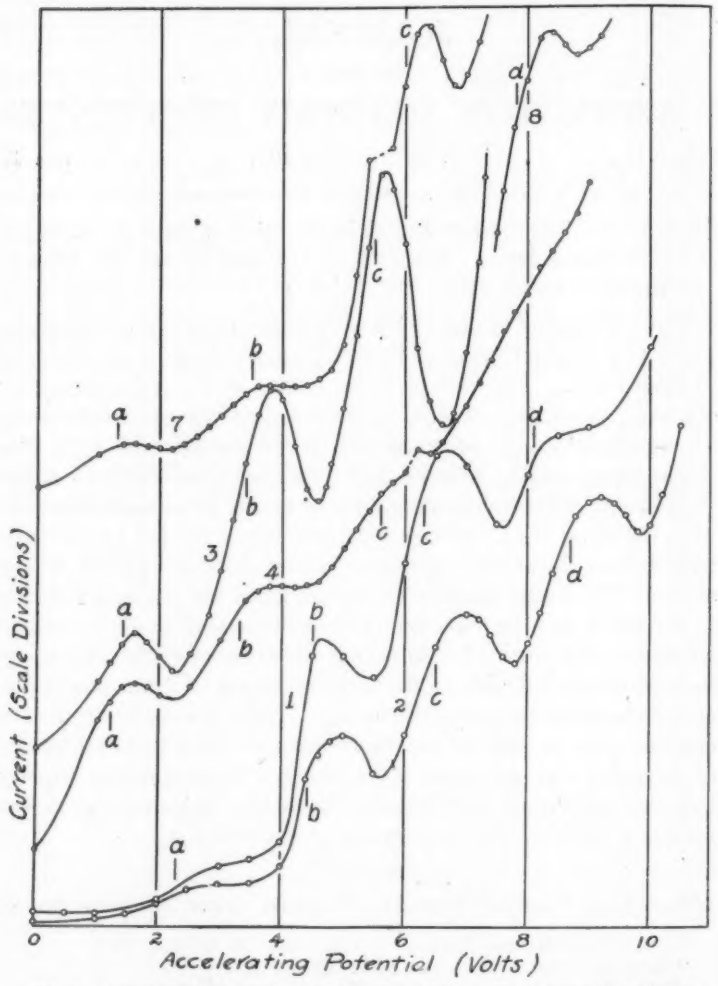


Fig. 1. Variation with accelerating potential of current to outside cylinder.

[7] COBLENTZ. Bull. Bur. Stds., 13: 470. 1916.

values obtained for $V$ on this basis are 4.88 volts for mercury and 3.79 volts for cadmium.

The second type of inelastic impact has been observed at 10.3[8] or 10.4 volts[9] for mercury and 8.92 volts[10] for cadmium. Collisions taking place at these potentials are characterized by the complete removal from the atom of one or more bound electrons, i.e., by ionization of the atom,[11] and by the emission of the complete spectrum of the vapor.[12] We may, following

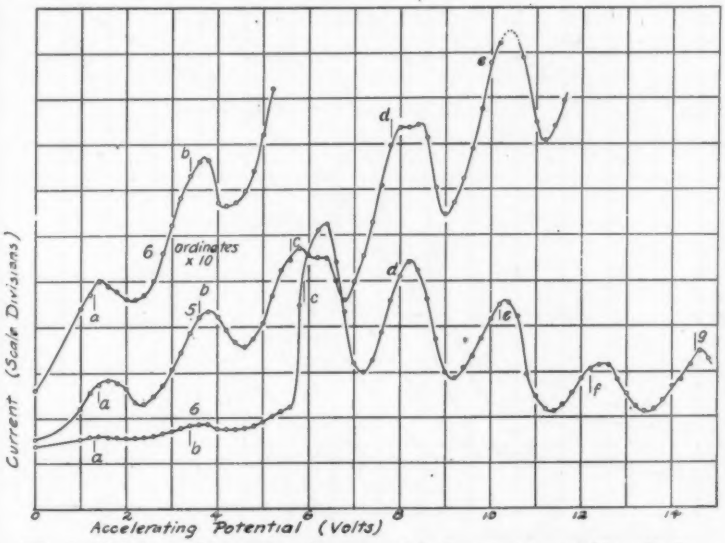


Fig. 2. Variation with accelerating potential of current to outside cylinder.

McLennan, calculate the ionizing potential on the basis of Bohr's theory of atomic structure from the limiting frequency $\nu = (1.5, S)$ in the spectra of these metals and obtain for mercury 10.41 volts and for cadmium 8.97 volts. The agreement between observed and calculated values of both resonance and

[8] TATE. Loc. cit.
[9] DAVIS and GAUCHER. Phys. Rev., 10: 101. 1917.
[10] TATE and FOOTE. Loc. cit.
[11] TATE. Loc. cit.; TATE and FOOTE. Loc. cit.
[12] MCLENNAN and HENDERSON. Loc. cit.

ionization potentials is well within the limits of experimental error.

The object of the present investigation is the experimental determination of the critical potentials for electrons in sodium vapor. The experimental arrangement was identical with that used by the writers in the work on cadmium vapor and the method of measurement that already described for the determination of critical potentials in mercury vapor.

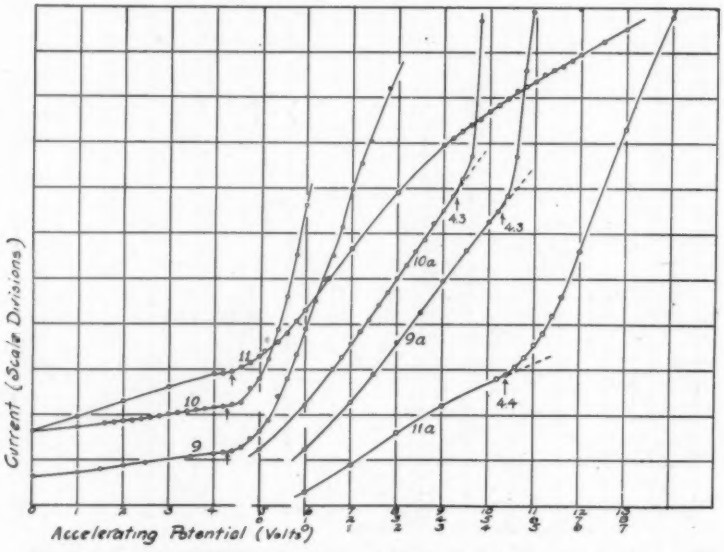


Fig. 3. Variation with accelerating potential of total current from hot wire. Upper abscissae values apply to curves 9, 10, 11; middle values to curve 10 *a*; and lower values to curves 9 *a* and 11 *a*.

The results of the present work are represented graphically by figures 1, 2, and 3. Curves 1 to 8, figures 1 and 2, show the variation with the accelerating potential between hot wire and gauze of that portion of the current which reaches the outside cylinder against a retarding field of about 0.8 or 0.9 volts. The sudden falling off in the rate of increase of current which takes place at the points *a*, *b*, *c*, *d*, etc., indicates that at the effective potentials of these points inelastic impact has taken place.

The correct value for the critical potential is obtained by taking the difference in potential between successive points, thus eliminating any effect of initial velocity. For reasons to be discussed later only the points *a* and *b* were used. The average value obtained for the difference in potential between *a* and *b* on curves 3 to 7 was 2.12 volts. Curves 1 and 2 were preliminary curves and not enough points were observed to permit of an accurate determination of the critical potentials.

TABLE 1

SUMMARY OF DATA ON SODIUM

| | APPLIED POTENTIALS AT RESONANCE | | | | | | | RESONANCE POTENTIAL | INITIAL POTENTIAL |
|---|---|---|---|---|---|---|---|---|---|
| Curve | a | b | c | d | e | f | g | b-a | |
| 1 | 2.3 | 4.5 | 6.3 | 8.1 | | | | | |
| 2 | 2.3 | 4.5 | 6.5 | 8.7 | | | | | |
| 3 | 1.4 | 3.4 | 5.5 | | | | | 2.0 | 0.6 |
| 4 | 1.2 | 3.3 | 5.6 | | | | | 2.1 | 0.9 |
| 5 | 1.4 | 3.6 | 5.6 | 7.8 | 10.0 | | | 2.2 | 0.8 |
| 6 | 1.3 | 3.4 | 5.9 | 8.0 | 10.2 | 12.2 | 14.5 | 2.1 | 0.8 |
| 7 | 1.3 | 3.5 | 6.0 | | | | | 2.2 | 0.9 |
| 8 | | | | 7.8 | | | | | |
| | | | | | | | Mean | 2.12 ±0.06 | 0.80 |

| | | |
|---|---|---|
| 9a | 4.3 | Applied potential for ionization. |
| 10a | 4.3 | Applied potential for ionization. |
| 11a | 4.4 | Applied potential for ionization. |
| | 4.33 | Mean applied potential. |
| | 0.80 | Initial potential. |
| | 5.13 | Ionization potential. |

The initial velocity of the electrons may be obtained from these curves directly. For example, in curve 6, the first resonance occurs at 1.3 volts and the second at 3.4 volts. The correct resonance potential is the difference of these two values or 2.1 volts. Hence the first resonance must have occurred at a true potential of 2.1 volts. The initial potential is the correction necessary to add to the applied potential of 1.3 volts to give

this value, viz. 0.8 volts. The mean value thus obtained for curves 3 to 7 was 0.80 volts.

Without changing conditions in any way the curves 9, 10, and 11, figure 3, representing the variation in total current from the hot wire with accelerating potential were obtained. Curves 9 *a*, 10 *a*, and 11 *a* are sections of the curves 9, 10, and 11 plotted on the same scale of coordinates used in figures 2 and 3. It is to be noted that there is no sudden change in the total current at points corresponding to *a* and *b*, etc., on the other curves. This indicates that no ionization results from the inelastic impact which occurs at 2.12 volts. There is, however, a sharp increase in current at an average applied potential of 4.33 volts. Correcting for the initial velocity as determined above gives 5.13 volts for the average value of the ionizing potential.

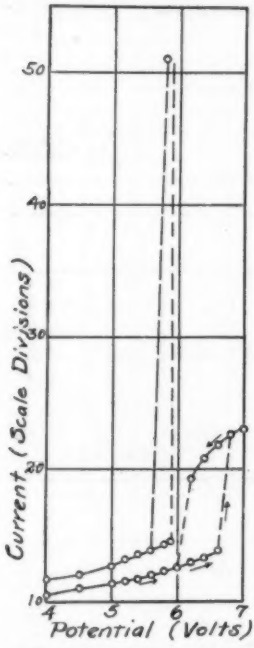


Fig. 4. Examples of discontinuous "total current" curves.

Simultaneously with the rapid increase in current at 4.33 volts there appeared a bright yellow glow about the hot wire.

It is to be emphasized that the critical points were chosen by plotting all curves on the same scale and estimating where the actual curves deviated by a constant predetermined small amount from the curve extrapolated beyond the critical point. Since we are dealing here with differences between similarly chosen points the element of arbitrariness in their choice is largely eliminated. The final results are tabulated in table 1.

With a rather high vapor pressure of sodium the total current curves showed a discontinuous break (see fig. 4) at some indeterminate potential. The current jumped to a very high value and, as the potential was decreased, remained very large until the potential was considerably lower than that at which the

sudden increase had taken place. It would then drop back, again discontinuously, to its original low value. Similar effects have been observed in mercury vapor. Continuous curves were obtained by decreasing the vapor pressure of the sodium.

The points of higher order *c*, *d*, *e* of curves 1 to 8 are of interest in that they are a combination of two overlapping effects. After ionization has set in at an observed potential of 4.33 volts it is to be expected that the electrons which start at this point will collide inelastically at potentials of 6.45, 8.57 volts, etc., whereas the electrons which had not been involved in an ionization would collide inelastically at 5.56, 7.68, etc. What is actually observed is a combination of the point 5.56 with 6.45, etc. (see especially curve 5 which shows distinct double maxima in these regions). On account of this overlapping no use was made of these points of higher order in the determination of critical potentials.

If, on the basis of Bohr's theory, we calculate the minimum wave length to be expected assuming a critical potential of 2.12 volts, we get $\lambda = 5830$ Å and it seems obvious that we are dealing here with the potential necessary to bring out the *D* lines. Using $\lambda = 5893$ Å we find for the critical potential necessary to excite the *D* lines 2.10 volts.

The minimum wave length corresponding to the observed ionizing potential is 2410 Å. The limiting wave length of the principle series of the sodium spectrum is 2412.63 Å.[13]

*Summary.*—(1) Electrons having a velocity corresponding to $2.12 \pm 0.06$ volts collide inelastically, without ionization, with the atoms of sodium vapor. The energy lost by the colliding electrons is probably radiated in light of wave lengths corresponding to the *D* lines. Assuming this to be the case the theoretical value of the resonance potential is 2.10 volts.

(2) Electrons having a velocity corresponding to $5.13 \pm 0.10$ volts are able to ionize sodium vapor and cause it to emit a brilliant yellow light. The theoretical value of the ionizing potential using the limiting wave length of the principal series in the sodium spectrum is 5.13 volts.

[13] Wood and Fortrat. Astrophys. Journ., **43**: 73. 1916.

(3) The experimental results of the present paper afford another instance of the fundamental correctness of deductions based upon Bohr's theory of atomic structures.

---

In a very interesting paper[14] which has appeared since this paper was written, Wood and Okano observe an emission of the *D* lines at a potential of 0.5 volts, and the appearance of the subordinate series (probably indicating ionization of the sodium vapor) at 2.3 volts. These values are much lower than those to be expected from the results of the present paper. It will be remembered that Hebb[15] has observed correspondingly low values for the potentials necessary to excite the single-lined and many-lined spectrum of mercury. The writers have observed a similar phenomenon in connection with a determination, which has just been completed, of the critical potentials for electrons in potassium vapor. It was found that the first resonance collision occurred at an effective applied potential of 0.2 volt (correcting for the potential drop along the hot wire). In all cases, however, the second resonance collision took place at a potential 1.60 volts higher than the first. This value (1.60 volts) is exactly that required, on the basis of Bohr's theory, to produce an emission of the fundamental lines ($\lambda$ = 7701.92 Å and $\lambda$ = 7668.54 Å) of the principal series of the potassium spectrum. Ionization of the potassium vapor was observed to take place at a potential roughly one volt higher than the second inelastic collision, i.e., at an effective potential of 3.2 volts + 1 volt, or 4.2 volts approximately. The theoretical value using the limiting frequency of the principal series of potassium is 4.33 volts.

It appears evident, therefore, that the electrons involved in producing these effects have initial velocities of about 1.4 volts—a value much greater than that to be expected. The reason for these high initial velocities is difficult to find. The presence of vapor or of a lime coating on the cathode seems necessary for their production, and it is not impossible that chemical forces

[14] Wood and Okano. Phil. Mag., **34**: 177. 1917.
[15] Hebb. Phys. Rev., **9**: 371. 1917.

are involved. It is suggested that a study of the relationship between the intensity of light emitted and the applied potential would prove of value as a spectroscopic determination of critical potentials.

PHYSICS.—*The photoelectric sensitivity of various substances.*[1] W. W. COBLENTZ and W. B. EMERSON, Bureau of Standards.

Some time ago an examination was made of various substances to determine their electrical sensitivity to light; and in view of the fact that some of the results obtained are at variance with the measurements made by Case,[2] it seems desirable to publish a summary of our observations.

Two of the herein described substances were examined for change in electrical conductivity caused by the action of light upon them, and all of them were examined for photoelectrical activity when they were charged to a negative potential in an evacuated bulb and exposed to light.

When the substances were examined for an increase in electrical conductivity, a potential of 2 to 6 volts was connected through a resistance of zero to 100,000 ohms into a circuit containing a d'Arsonval galvanometer and the substance under investigation. In most cases the substances were slightly conducting when not exposed to light, so that the "dark current" had to be annulled by joining a counter e.m.f. through a resistance of 10,000 ohms to the terminals of the galvanometer. This counter e.m.f. was obtained by shunting across a resistance of 100 ohms which was in series with a cell of 2 volts and a variable resistance of zero to 70,000 ohms.

The source of light, when not otherwise specified, was a 16-c.p. carbon incandescent lamp, placed at a distance of 10 cm. from the substance under investigation. One disappointing feature of this investigation is that no substance was found which is comparable in sensitivity with the potassium photoelectric cell and with the selenium cell.

[1] To be published in full in the Bulletin of the Bureau of Standards.

[2] CASE. Phys. Rev., 9: 305. 1917.

SUBSTANCES EXAMINED

*Gallium.* The material examined was the highly purified metal prepared and supplied by Dr. H. S. Uhler. This metal was solid, thus differing from the impure material, which is a liquid. It was melted and solidified over a platinum wire sealed into a glass bulb, thus forming the negative electrode of a photoelectric cell from which the air was exhausted. The anode was a loop of platinum wire, situated at a distance of about 12 mm. above the gallium electrode.

A potential of 340 volts was applied to the cell which was connected to a sensitive iron-clad Thomson galvanometer ($i = 5 \times 10^{-10}$ amp.).

The results obtained proved disappointing, this metal being quite insensitive to light. When the cell was exposed to daylight the photoelectric current produced a deflection of only 4 to 5 mm., whereas similarly exposing a potassium photoelectric cell the photoelectric current was sufficient to give a deflection beyond the range of the scale.

*Silver sulphide.* The sample examined was a thin flexible strip, 6 by 10 mm. in area, prepared by Mr. G. W. Vinal.[3] In one test the silver sulphide formed the negative electrode of a photoelectric cell (evacuated glass bulb about 5 cm. diameter with a ring of platinum wire for the anode) similar to the gallium cell just described. It was connected through an iron-clad Thomson galvanometer to a battery of 340 volts. When exposed to daylight a deflection of perhaps 1 to 2 mm. was observed, but no deflection resulted from exposure to the standard carbon lamp.

In the second test, copper wires were melted to the ends of a strip (3 by 5 by 0.3 mm.) of silver sulphide which was connected in series with a high resistance, a storage cell of 2 volts, and a d'Arsonval galvanometer. When exposed to the standard lamp, the galvanometer deflection was 10 mm. In another sample about 2 cm. long, the ends joining the copper wires were covered to prevent thermoelectric currents. The exposed area

[3] VINAL. Bur. Standards Scientific Paper No. 310.

was 14 by 4 mm. The radiation from the standard lamp produced a deflection of 13 to 17 mm. Both samples were quick acting, and after exposure to light there was no lag such as obtains in selenium in recovering its dark resistance.

*Selenium.* A crystal of selenium, prepared by Dr. F. C. Brown[4] and having a receiving surface of less than one sq. mm., when exposed to the standard lamp gave a deflection of more than 50 cm., which shows its great sensitivity as compared with other substances.

The mounting of the selenium crystal consisted of metal electrodes between which the crystal was held by compression. When operated as a photophone, by connecting the selenium crystal with an audion amplifier as described on a subsequent page, a loud musical note was obtained.

*Tellurium.* This metal is said to change in resistance when exposed to light. The present tests were made upon a mirror of tellurium deposited upon a glass plate by cathode disintegration. Suitable terminals were attached to a sample about 4 by 50 mm. No change in conductivity was observed when it was exposed to light.

*Boleite.* The sample of boleite [3Pb Cl (OH) . Cu Cl (OH) + Ag Cl], from Boleo, Mexico, examined was a single rectangular crystal 3 by 3 by 1.5 mm. It was held by compression between copper electrodes. No change in conductivity was observed when the crystal was exposed to daylight or to the standard incandescent lamp.

*Stibnite.* Samples of this same specimen of stibnite, $Sb_2S_3$, were supplied to Elliot[5] for investigation. The purpose of the present investigation was to obtain a comparison of its sensitivity with that of other substances containing antimony.

The size of one sample examined was 4 by 7 by 0.5 mm. Terminals were attached to it by heating a copper wire to incandescence in a gas flame and bringing it in contact with the plate of stibnite.

The standard carbon lamp caused a deflection of 5 cm. Stib-

[4] BROWN. Phys. Rev., (2) **4**: 85. 1914.
[5] ELLIOT. Phys. Rev., (2) **5**: 53. 1915.

nite may be considered as sensitive as boulangerite, to be mentioned presently, but the deflection drifted, due to the decrease in resistance with time already noticed by other observers.

*Boulangerite.* The specimen of boulangerite ($3PbS.Sb_2S_3$, Irkutsk, Siberia) investigated was obtained from the Smithsonian collection, No. 78395. Several samples were examined. In one sample, 4 by 7 by 0.8 mm., the electrodes consisted of copper wires melted into the material as just described. The radiation from the standard lamp gave a deflection of 10 to 20 cm.

Another sample, 1 by 1.2 by 2 mm., held by compression between two heavy electrodes of copper, when exposed to the standard incandescent lamp produced a deflection of 2 to 3 cm., which is comparable with the preceding when one considers the size of the exposed surfaces.

Although this substance seems fairly sensitive, it did not appear to be sufficiently so to justify an investigation of its spectral sensitivity with a view of using this mineral as a selective radiometer.

*Jamesonite.* ($2PbS.Sb_2S_3$; Smithsonian collection No. 12,500; from Cornwall, England.) The sample examined (size 2 by 7 by 1 mm.) had the copper wire terminals attached by fusing the incandescent wire into the material. The standard lamp gave a deflection of only 1 to 2 cm., which seems to indicate that this material is not so light-sensitive as is boulangerite.

Mixtures of galena, PbS, and stibnite, $Sb_2S_3$, in various proportions were melted in a crucible and poured upon a plate of metal. Several samples, 5 by 10 by 0.5 mm., were examined, but none of them gave any indication of light-sensitiveness (change in resistance) when exposed to daylight or to the standard incandescent lamp.

*Bismuthinite.* Bismuthinite, $Bi_2S_3$, was obtained from the Smithsonian collection, No. 85071, from Jefferson County, Montana. This is the most interesting substance examined, in view of the diverse results obtained and the explanation offered therefor.

The sample of bismuthinite examined consisted of a non-homogeneous mass of acicular crystals, which was easily crushed

into numerous fine needle-like crystals. The first sample examined was a small mass of crystals (size 1 by 1 by 0.7 mm.) held by compression between two heavy electrodes of copper. When the crystal was exposed to the standard carbon lamp no change in conductivity could be detected with certainty.

A second sample, 3 by 6 by 1 mm., had the copper wire terminals attached by fusion, as already described. The e.m.f's applied were the same as for the preceding sample. When exposed to the standard lamp no change in conductivity was observed. These results being contradictory to those published by Case[6] who used a three stage audion amplifier to detect the change in conductivity of the crystals, the foregoing experiments were repeated in the manner described by him. For this purpose the light from an acetylene flame shining through a slit 2 by 10 mm. was focused upon the crystal by means of a triple achromatic lens, 6 cm. in diameter and 18 cm. focal length. The light was interrupted by means of a sectored disk having 15 openings and operated by means of an electric motor, the speed of which could be varied. The usual speed gave 240 interruptions per second. The crystal was connected to a three stage audion amplifier and telephone receiver. A crystal of selenium or a selenium cell produced a loud note, but the samples of boulangerite and jamesonite, which by previous tests were light-sensitive, did not give a musical sound in the telephone.

The sample of bismuthinite with electrodes sealed on produced no audible note when exposed to light.

At least a dozen samples of bismuthinite held by compression between heavy copper electrodes were examined in connection with the amplifier. Of this number only two samples appeared to be light-sensitive. One sample produced only a faint sound in the telephone receiver. The second sample produced a loud note in the telephone. The sound was the loudest when the crystal was exposed along the line of contact with the copper electrode. Covering the crystal with red glass did not reduce the loudness of the note very much, indicating that the effect is due to heating of the material. Unfortunately, this crystal was

[6] Loc. cit.

crushed while under investigation. Prolonged tests on other samples gave negative results as regards the production of sound.

In view of the fact that the tests made with a sensitive galvanometer failed to show an increase in conductivity when bismuthinite was exposed to light, it appears that the change in conductivity which was observed when a certain specimen was exposed to intermittent flashes of light (photophone or, rather, radiophone) is the result of a thermal change within the crystal, or perhaps a change in the contact resistance at the electrodes.[7] In this connection the following experiments on thin strips of metals are of interest.

*Platinum and gold.* In conclusion it is of interest to record the results obtained when using thin blackened strips of platinum and of gold-leaf as radiophones, by connecting them through a battery to an amplifier.

These blackened strips were warmed intermittently by exposing them through a rotating sectored disk to the acetylene flame, as already described.

When a sensitive platinum bolometer receiver was used as a radiophone, the sound produced in the telephone was not very audible. This no doubt was due to the great heat capacity of the material which prevented the rapid alternations in resistance, and hence in electric current, from being of sufficient magnitude to affect the telephone receiver.

Using a lightly smoked strip (6 by 2.5 mm.) of gold-leaf, the ends of which were clamped between thin (0.02 mm.) strips of tin, the sound produced in the telephone receiver was as loud as was observed in the photophone made of selenium.

This device was mounted in a glass bulb which could be evacuated. As was to be expected, there was no marked difference in the intensity of the sound produced when operated in air and in a vacuum.

In the gold-leaf radiophone as used, the limit of audibility was attained for a light (radiant power) intensity of $4.8 \times 10^{-5}$

[7] It would be interesting to determine whether the effect is dependent upon the axial direction of exposure. In the present case the needle-crystals were parallel to the electrodes.

watts. Using a larger receiver and amplifier and a larger current (which was 0.2 amp. in the present tests) through the receiver, the sensitivity could be greatly increased.

## SUMMARY

This paper summarizes the results of an investigation of various substances (1) for an increase in electrical conductivity caused by the action of light upon them, and (2) for electrical discharging activity when they were charged to a negative potential in an evacuated chamber and exposed to light.

Pure gallium and silver sulphide were found to have but small photoelectric discharging action when charged to a negative potential and exposed to light.

No change on exposure to light was observed in the electrical conductivity of tellurium, boleite, bismuthinite, and mixtures of the sulphides of lead and antimony.

An increase in electrical conductivity on exposure to light was observed in crystals of selenium, stibnite, boulangerite, jamesonite, and silver sulphide.

Experiments are described in which crystals of bismuthinite were joined through a battery to the grid circuit of an audion amplifier and a telephone. A change in current in this circuit affected the telephone. The light stimulus was interrupted by means of a rotating sectored disk, as used in Bell's selenium photophone. When using a cell or crystal of selenium the fluctuations in light intensity produced a sufficient change in conductivity to cause a musical note in the telephone. Similarly, in several samples of a crystal of bismuthinite a change in conductivity was produced, which caused an audible sound in the telephone. However, from various tests it is believed that this is not a true photoelectrical change (increase) in conductivity, but is due to a thermal resistance change within the crystal or to a change of resistance at the point of contact of the crystal with the metal electrodes between which the crystal was held by compression.

Experiments are described in which a thin blackened strip of platinum or of gold-leaf is joined through a battery to an audion amplifier. The variation in temperature and hence in the resistance of and in the current through the strip, caused by the fluctuation in intensity of the intermittent light, was sufficient in magnitude to produce an audible sound in the telephone receiver.

GENETICS.—*The average correlation within subgroups of a population.* SEWELL WRIGHT, Bureau of Animal Industry.

In studying the relationship of characters it often happens that the available data consist of a number of more or less differentiated groups, each one of which is by itself rather small for the calculation of a coefficient of correlation. Sufficiently large numbers can be obtained by combining all into one table, but if this is done the correlation due to differentiation of the subgroups among themselves complicates the interpretation. The coefficients for the whole population and for the means of the subgroups are easily calculated, but the calculation of coefficients within the subgroups may be a very tedious task if these are numerous.

It seems desirable therefore to have a method by which the average correlation for the subgroups can be derived directly from the distribution surfaces of the whole population and that of the means of the subgroups. The very simple formula discussed below has been useful to the writer and does not seem to be well known.

Assume that a population is composed of a number of subgroups which may be expected, within the limits of random sampling, to show the same correlation between two variables $x$ and $y$ and the same standard deviations. They may, however, be of varying sizes and be differentiated from each other significantly with respect to the mean values of $x$ and $y$.

Let $\sigma_{x(g)}$, $\sigma_{y(g)}$, $r_{xy(g)}$ be the average standard deviations and the average correlation between $x$ and $y$ for the individuals within a single subgroup. Let $\sigma_{x(m)}$, $\sigma_{y(m)}$, $r_{xy(m)}$ be the corresponding values for the means of the subgroups weighting each mean

with the number of individuals involved. Let $\sigma_{x(t)}$, $\sigma_{y(t)}$, $r_{xy(t)}$ be the values for the total population. The average standard deviations within the subgroups can be calculated at once, as the variability of the whole population is compounded of the variability of the means of the subgroups and the independent variability of the individuals about these means.

Thus,
$$\sigma^2_{x(t)} = \sigma^2_{x(m)} + \sigma^2_{x(g)}$$
$$\sigma^2_{y(t)} = \sigma^2_{y(m)} + \sigma^2_{y(g)}$$

It is evident that the mean values of $x$ and $y$ for the total population are identical with those for the weighted means of the subgroups. Take the intersection of these means as origin and consider the contribution of a given subgroup to the term $\Sigma X_{(t)} Y_{(t)}$ in the formula for the coefficient of correlation for the total population.

$$r_{xy\,(t)} = \frac{\Sigma X_{(t)} Y_{(t)}}{n_{(t)} \sigma_{x\,(t)} \sigma_{y\,(t)}}$$

Let $X_{(m)}$, $Y_{(m)}$ be the deviations of the means of the subgroup from the origin. Let $X_{(g)}$, $Y_{(g)}$ be the deviations of any point within the subgroup from the center of the latter. $X_{(m)} + X_{(g)}$, $Y_{(m)} + Y_{(g)}$ are the coordinates of the point. For any such point there is a point of equal frequency at an equal distance on the opposite side of the center of the subgroup in the ideal case in which the subgroup is perfectly symmetrical about two perpendicular axes. Normal chance distributions tend to approach this ideal case. The coordinates of this point are $X_{(m)} - X_{(g)}$, $Y_{(m)} - Y_{(g)}$.

The sum of the products of the coordinates of such symmetrically placed points is as below.

$$\begin{array}{l} X_{(m)}\,Y_{(m)} + X_{(m)}\,Y_{(g)} + X_{(g)}\,Y_{(m)} + X_{(g)}\,Y_{(g)} \\ X_{(m)}\,Y_{(m)} - X_{(m)}\,Y_{(g)} - X_{(g)}\,Y_{(m)} + X_{(g)}\,Y_{(g)} \\ \hline 2X_{(m)}\,Y_{(m)} \qquad\qquad\qquad + 2X_{(g)}\,Y_{(g)} \end{array}$$

The sum of the products for all points in the subgroup, taken thus in pairs, is $n_{(g)} X_{(m)} Y_{(m)} + \Sigma X_{(g)} Y_{(g)}$ where $n_{(g)}$ is the number in the subgroup.

The correlation within a subgroup is

$$r_{xy\,(g)} = \frac{\Sigma X_{(g)} Y_{(g)}}{n_{(g)}\,\sigma_{x\,(g)}\,\sigma_{y\,(g)}}$$

$$\Sigma X_{(g)} Y_{(g)} = r_{xy\,(g)}\,\sigma_{x\,(g)}\,\sigma_{y\,(g)}\,n_{(g)}$$

The correlation and standard deviations within a subgroup are assumed constant. Hence $n_{(g)}$ is the only variable in the expression above.

Combining all subgroups:

$$r_{xy\,(t)} = \frac{\Sigma n_{(g)} X_{(m)} Y_{(m)} + r_{xy\,(g)}\,\sigma_{x\,(g)}\,\sigma_{y\,(g)}\,\Sigma n_{(g)}}{\sigma_{x\,(t)}\,\sigma_{y\,(t)}\,\Sigma n_{(g)}}$$

$$= \frac{r_{xy\,(m)}\,\sigma_{x\,(m)}\,\sigma_{y\,(m)} + r_{xy\,(g)}\,\sigma_{x\,(g)}\,\sigma_{y\,(g)}}{\sigma_{x\,(t)}\,\sigma_{y\,(t)}}$$

Thus the relation between the correlations and standard deviations of the total population, of the weighted means of subgroups, and of the individuals within an average subgroup are expressed by the following formula:

$$r_{xy(t)}\,\sigma_{x(t)}\,\sigma_{y(t)} = r_{xy(m)}\,\sigma_{x(m)}\,\sigma_{y(m)} + r_{xy(g)}\,\sigma_{x(g)}\,\sigma_{y(g)}$$

The following example deals with correlation between weight at birth and weight at the age of a year in male guinea-pigs born in litters of three in an inbreeding experiment carried on by the Animal Husbandry Division. In this experiment, 24 families have been developed by exclusively brother-sister matings from 24 original pairs. These 24 families have become strongly differentiated in various respects which can not be ascribed merely to variation in vigor. The present data involve records collected up to a certain date and include animals from the first to the 15th generation of inbreeding. There were 560 guinea-pigs in all families combined. This mixed population gives a correlation of $+ 0.375 \pm 0.024$. The correlations of the means of the 24 families, each weighted by the number of individuals, gives $+ 0.630 \pm 0.083$. In order to discover the average correlation within the families apart from the differentiation between families, correlations were calculated separately for the 8

largest families, containing 297 guinea-pigs. These contained, between 32 and 45 guinea-pigs each. Naturally, the coefficients varied greatly but all but one were positive and the weighted average came out $+ 0.256 \pm 0.036$, showing a substantial correlation. This, however, does not use all the data. A calculation directly from the correlation and standard deviations of the total population and the array of means, by the method suggested in this paper, gives $+ 0.308 \pm 0.026$ as the average within a family. This agrees reasonably well with the first calculation, uses all the data and involves very much less labor. Table 1 shows the constants used in calculating the average correlation within families and the averages derived from the 8 largest families as a check. $\sigma_b$ and $\sigma_y$ are the standard deviations, in grams, of birth weight and year weight respectively.

TABLE 1

CONSTANTS USED IN CALCULATIONS

| | $\sigma_b^2$ | $\sigma_y^2$ | $\sigma_b$ | $\sigma_y$ | $\sigma_b\sigma_y$ | $r_{by}\sigma_b\sigma_y$ | $r_{by}$ |
|---|---|---|---|---|---|---|---|
| Total (560 pigs).... | 130.53 | 14,852 | 11.425 | 121.87 | 1,392.4 | 522.15 | $+0.375 \pm 0.024$ |
| 24 family means.... | 20.50 | 4,837 | 4.528 | 69.55 | 314.9 | 198.39 | $+0.630 \pm 0.083$ |
| Average family (deduced)..... | 110.03 | 10,015 | 10.49 | 100.08 | 1,049.8 | 323.76 | $+0.308 \pm 0.026$ |
| Average 8 families with 297 pigs..... | 108.78 | 8,915 | 10.43 | 94.42 | | | $+0.256 \pm 0.036$ |

GENETICS.—*A new case of metaphanic variation in grasses and its significance.* J. DUFRENOY, Station Biologique d'Arcachon. (Communicated by K. F. Kellerman.)

In his recent work on the *Hybrids of Zea ramosa and Zea tunicata*, G. N. Collins described these two mutants of maize as being ancestral forms. In crossing them "the hope was entertained that their combination might bring to light still other ancestral characters." This hope was not fulfilled, but important data were obtained and the conclusions brought forth seem to have a wide bearing.

We found them to apply fairly well to the case of *Dactylis glomerata*.

Two forms of *Dactylis glomerata* have been described, the true *D. glomerata* with a dense inflorescence, the branches at its base being less than 5 mm. long, and *D. glomerata ramosa* with a divided inflorescence, the basal parts being supported by branches 10 to 60 mm. long. The specialized character of *D. glomerata* is the suppression of the basal branches in the inflorescence, the whole inflorescence being the homologue of the terminal inflorescence of *D. glomerata ramosa*. This latter, which is less differentiated, may be considered an ancestral form.

In a meadow at Barèges (Hautes-Pyrénées, France) careful examination of hundreds of *D. glomerata* and *D. glomerata ramosa* led to the discovery: (1) of two inflorescences, bearing sterile spikelets, to be compared with the sterile ear of *Zea tunicata*;[1] (2) of a case of metaphanic variation which is most remarkable as it actually brings to light ancestral characters.

Green foliage organs, 23 to 25 mm. long, developed between the glumes, some of which yielded ♂ and ♀ reproductive organs. Some of the foliage organs enclosed normal, rudimentary, or abnormal stamens and pistils, or rudimentary leaves developed where pistils should have been. These metaphanic variations may be compared with those observed by Collins in the terminal inflorescence of full tunicate plants of maize. Successive transverse sections displayed all gradations in the forms of ♂ reproductive organs from the microsporangia of thallophytes to the stamens of flowering grasses.

Twelve microsporangia were imbedded in the parenchymatous tissue at the base of the foliage organ, which was thus a true homologue of the thallus of nonflowering plants. Some of these microsporangia were rudimentary and contained cells scarcely different from the parenchymatous neighboring cells, while others contained pollen-grains surrounded by nutritive cells. In the upper sections these microsporangia became more and more individualized and were freely grouped two by two as stamens.

[1] COLLINS, G. N. Journ. Agr. Research, **9**: pl. 15.

The nondifferentiated foliage organ which bears ♂ and ♀ reproductive organs, and continues to act as an assimilating organ, being thus at the same time green and fertile, may be considered to represent one of the possible forms of the ancestral organs of grasses.

From the data presented the following conclusions may be drawn, which confirm the theories of Bower, MacDougal, and Dufrenoy:

Organs of grasses were at first all fertile but most of them became sterile under the pressure of ecologic factors. The vegetative activity overshadowed the reproductive activity and most organs become assimilating organs, viz., leaves. A few remained fertile, and responded in diverse ways to their reproductive specialization, attaining their greatest differentiation in ordinary maize.

BIBLIOGRAPHY

COLLINS, G. N. *Hybrids of* Zea ramosa *and* Zea tunicata. Journ. Agr. Research, **9**: 383–395, pl. 13–21.

MACDOUGAL, D. T. *Aridity and evolution.* Plant World, **12**: 221.

DUFRENOY, J. *Les données actuelles et les problèmes de la phytogéographie.* (Literature cited.) Rev. Gén. Sci., **27**: No. 10.

ORNITHOLOGY.—*Diagnosis of a new pycnonotine family of Passeriformes.* HARRY C. OBERHOLSER, Biological Survey.

It requires but a superficial examination to discover that the genus *Irena* is out of place among the Pycnonotidae. Apparently it has been referred to that family because of its conspicuous nuchal hairs, which are so characteristic a feature of the bulbuls; and because of the lack of a better place.

That this disposition has not been considered satisfactory is evidenced by Dr. R. B. Sharpe's reference of *Irena* to the Dicruridae,[1] which action was, however, soon, and properly, repudiated by Dr. Sharpe himself.[2] As a matter of fact, the fairy bluebirds, as the members of the genus *Irena* are called, with their metallic

[1] Cat. Birds Brit. Mus., **3**: 265. 1877.
[2] Cat. Birds Brit. Mus., **6**: 174. 1881.

plumage and heavily plumed nostrils, do, at first glance, very much resemble the drongos (family Dicruridae); but the possession of twelve instead of ten rectrices definitely excludes them from that group. Since, as above indicated, the birds now comprised in the genus *Irena* Horsfield are not properly referable to the Pycnonotidae or to any other recognized family, it becomes necessary to create for them a new group, to be called

IRENIDAE, fam. nov.

*Diagnosis.*—Readily differentiated from the Pycnonotidae by the strongly corvine bill and the densely and entirely feathered nostrils and nasal fossae.

*Family characters.*—Bill thick and heavy, but somewhat compressed, the culmen rather sharply ridged, the gonys rounded; terminal portion of maxillar tomia notched; mental apex opposite anterior end of nasal fossae; nostrils small and subrounded, situated in the anterior end of nasal fossae, and entirely and thickly covered with closely appressed antrorse feathers and bristles; head completely feathered; nuchal hairs present and of moderate length; tail of twelve stiffish feathers, slightly rounded, and making up nearly half the total length of bird; wings rather long and rounded; tertials short; first (outermost) primary spurious, but more than one-half the length of second; feet rather small, the claws moderately developed; tarsi short, scutellate, but sometimes rather indistinctly so.

*Type genus.*—*Irena* Horsfield.

*Remarks.*—The birds of this new family comprise eight current species, two of which are, however, but subspecies, and an additional new subspecies, hereinafter described. Authors have hitherto included all these in the single genus *Irena*, but structural differences necessitate the division of this into two genera, as follows:

**Irena** Horsfield

*Irena* Horsfield, Trans. Linn. Soc. Lond., ser. 1, XIII, pt. 1, May, 1821, p. 153 (type by monotypy, *Coracias puella* Latham).

*Generic characters.*—Tail rather long, about four-fifths of wing; lower tail-coverts falling short of end of tail by more than one and one-half times the length of tarsus; and upper tail-coverts falling short of end of tail by two or more times the length of tarsus.

*Type.—Coracias puella* Latham.

In the original diagnosis of *Irena* the only species that Horsfield cites is "Coracias puella, *Lath. Ind. Orn.* 171," with which he misidentifies Javan specimens of the species not until long afterward described as *Irena turcosa* by Walden. The type of this genus must, therefore, be the only species mentioned, *Coracias puella* Latham; not, as Sharpe[3] states, *Irena turcosa* Walden; particularly since the latter had no standing whatever at the time of the institution of the generic name *Irena*.

Of the forms now allotted to the restricted genus *Irena*, one, *Irena ellae* Steere, is certainly but a subspecies of *Irena melanochlamys* Sharpe, as individual variations in these two overlap the differences. With this change, the species of this group will be as follows:

*Irena melanochlamys melanochlamys* Sharpe.
*Irena melanochlamys ellae* Steere.
*Irena cyanogastris* Vigors.
*Irena puella* (Latham).
*Irena tweeddalii* Sharpe.

**Glauconympha,** gen. nov.

*Generic characters.*—Similar to *Irena* Horsfield, but tail shorter, only three-fourths of the length of wing; lower tail-coverts much longer, falling short of end of tail by less than length of tarsus, and sometimes reaching even beyond the end of tail; and upper tail-coverts much longer, falling short of end of tail by not more than the length of tarsus.

*Type.—Irena cyanea* Begbie.

The bird from Borneo and Sumatra, *Irena crinigera* Sharpe, is by individual variation subspecifically connected with *Irena*

[3] Cat. Birds Brit. Mus., **6**: 174. 1881.

*cyanea* from the Malay Peninsula, and must therefore stand as *Glauconympha cyanea crinigera*. Its name *criniger* is a Latin adjective (not a noun, as some authors apparently think) of which the feminine nominative is *crinigera*, as above written. Birds of this species from the Barussan Islands, off the western coast of Sumatra, are found to differ subspecifically from the typical race of the mainland, and as they are apparently undescribed, may be called:

*Glauconympha cyanea megacyanea*, subsp. nov.

*Subspecific characters.*—Similar to *Glauconympha cyanea crinigera* from Borneo and Sumatra, but larger; female with both upper and lower parts darker, more bluish (less greenish).

*Description.*—Type, adult female, No. 179254, U. S. Nat. Mus., Pulo Tuanku, Banjak Islands, January 23, 1902; Dr. W. L. Abbott. Upper surface dusky green blue No. 1,[4] but the tips of most of the feathers chessylite blue, and the interscapulum with a more greenish shade, the upper tail-coverts dark chessylite blue; tail brownish black, the middle pair of rectrices and outer webs of the three adjoining pairs, dark green blue slate; wings blackish fuscous, the lesser coverts dusky green blue No. 1, the broad edgings of median and greater coverts and tertials, and narrow margins of primary coverts, secondaries, and a few of the inner primaries, dark greenish blue like the interscapulum; lores and nasal feathers between neutral gray and deep neutral gray; sides of head and neck like the interscapulum; throat greenish blue, between dark gobelin blue and terre verte green; breast dull jouvence blue; abdomen dull, somewhat greenish capri blue; crissum dark orient blue; lining of wing fuscous, the outer feathers edged with greenish blue; "iris red; bill and feet black."

*Measurements.*—Male:[5] wing, 115–124 (average, 119.9) mm.; tail, 82.5–91 (86.6); exposed culmen, 21–23.5 (22.3); height of

[4] The colors here mentioned are based on Mr. Ridgway's "Color Standards and Color Nomenclature."

[5] Eleven specimens, from South Pagi Island, Nias Island, Pulo Mansalar, the Batu and Banjak Islands, western Sumatra.

bill at base, 9–10 (9.6); tarsus, 16–18.5 (17.5); middle toe without claw, 14–14.5 (13.7).

Female:[6] wing, 118–119 (average, 118.6) mm.; tail, 85–91 (88.1); exposed culmen, 23.5–24.5 (23.8); height of bill at base, 9.5–10.5 (10); tarsus, 17.5–19 (18.1); middle toe without claw, 14–15 (14.5).

*Geographic distribution.*—Nias, Mansalar, the Pagi, Batu, and Banjak Islands, with doubtless others of the Barussan chain off the western coast of Sumatra.

The subjoined measurements of *Glauconympha cyanea crinigera*, from Bornean and Sumatran specimens, are added here for convenience of comparison with those of the present new race:

Male.—Wing, 113.5–119 (average, 116) mm.; tail, 74–84.5 (81.5); exposed culmen, 21–23 (21.8); height of bill at base, 9–10.5 (9.5); tarsus, 15–18 (16.3); middle toe without claw, 13–14 (13.5).

Female.—Wing, 114–118 (average, 115.6) mm.; tail, 82–88 (84); exposed culmen, 22–24 (23.2); height of bill at base, 9–10.5 (9.6); tarsus, 16.5–19 (17.3); middle toe without claw, 14–14.5 (14.3).

The species and subspecies referable to the new genus *Glauconympha* are as follows:

*Glauconympha turcosa* (Walden).
*Glauconympha cyanea cyanea* (Begbie).
*Glauconympha cyanea crinigera* (Sharpe).
*Glauconympha cyanea megacyanea* Oberholser.

[6] Three specimens, from South Pagi Island, Nias Island, and the Banjak Islands, western Sumatra.

## ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this JOURNAL and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

RADIATION.—*The calculation of the constants of Planck's radiation equation; an extension of the theory of least squares.* HARRY M. ROESER. Bureau of Standards Scientific Paper No. 204 (Bull. Bur. Stds., **14**: 31–77). 1917.

The problem of computing from experimental data the constants, $c_1$ and $c_2$, of Planck's radiation equation for the distribution of energy in the spectrum of a black body is attacked by the method of least squares. The data were furnished by Dr. W. W. Coblentz. The observation equations were reduced by taking logarithms of both sides and assigning proper weights to the equations so transformed. The method of assigning weights is given in a general form that can be adapted to any scheme of transformation. H. M. R.

PHYSIOLOGICAL OPTICS.—*The luminous radiation from a black body, and the mechanical equivalent of light.* W. W. COBLENTZ and W. B. EMERSON. Bureau of Standards Scientific Paper No. 305 (Bull. Bur. Stds., **14**: 255–268). 1917.

In this paper the visibility of radiation by the average eye is applied to radiation problems, including the luminous energy emitted by a black body at various temperatures, the luminous efficiency, the Crova wave-length, and the mechanical equivalent of light. The visibility curve of the average eye (125 observers) gives a mechanical equivalent of 1 lumen = 0.00161 watt of radiant energy of maximum visibility. Various other determinations give values varying from 0.00157 to 0.00160 watt. The most reliable data now available indicate a value of 1 lumen = 0.0016 watt of radiant energy of maximum visibility, or 1 watt = 625 lumens = 49.8 candles of radiant energy of maximum luminous efficiency. W. W. C.

# PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

## THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 791st meeting was held at the Cosmos Club, May 26, 1917. President BUCKINGHAM in the chair; 33 persons present. The minutes of the 790th meeting were read in abstract and approved.

Mr. C. F. MARVIN gave an illustrated paper on *Aerology in aid of aeronautics.* (No abstract.)

*Discussion:* The paper was discussed by Messrs. BUCKINGHAM, HERSEY, WHITE, and SWEET. Mr. LITTLEHALES mentioned the systematic rotation of wind velocity with change in altitude.

*Informal communications*: Mr. HUMPHREYS gave an explanation of the formation of the two kinds of sun dogs, or haloes, by reflection. Mr. BUCKINGHAM considered one application of the principle of dimensional homogeneity. In a communication about three years ago, the speaker had enunciated a certain theorem concerning the forms of physical equations, as a convenient formulation of the principle of dimensional homogeneity. The present communication referred to the further elucidation of the term "complete equation." By means of Lord Rayleigh's problem of the gravitational oscillations of a liquid spheroid, two methods were illustrated for treating universal constants which might be involved in the phenomenon described by the equation in question. It was further remarked that a similar choice of methods was available for dimensional constants which were not universal, and that one of the methods introduced a considerable simplification into the algebra of the process.

DONALD H. SWEET, *Secretary.*

## ANNOUNCEMENT OF PROGRAM OF THE ANTHROPOLOGICAL SOCIETY OF WASHINGTON

During the season from October, 1917 to April, 1918, inclusive, the Anthropological Society of Washington, D. C., will provide a very interesting program of papers or lectures chiefly concerned with divers nations of Europe and the East now at war or likely to be involved before long, including especially some of our less known and smaller allies. The general plan of most of these monographs will be a résumé of earliest known data, racial origins, shiftings and blendings, historical development, and present status, aiming to further a more thorough acquaintance with these peoples, their characteristics and capabilities, and the causes which have made them what they are. The appended schedule may be subject to some changes in detail as the season advances and is now necessarily incomplete as to one or Two items, but will give a sufficient idea of what is to be expected. the society meets at 4.30 p.m. in rooms 42–43 of the new building of the National Museum on alternate Tuesdays, beginning October 2, 1917.

PROGRAM

Oct. 2, 1917: Dr. ALES HRDLICKA: *Bohemia and the Bohemians.*
Oct. 16, 1917: Dr. MITCHELL CARROLL: *The story of Greece.*
Nov. 6, 1917: Prof. JAMES H. GORE: *Belgium.*
Nov. 20, 1917: Mr. GEORGE J. ZOLNAY: *Roumania, past and present.*
Dec. 4, 1917: Dr. AMANDUS JOHNSON: *Scandinavia.*
Mr. JUUL DIESERUD: *Certain customs of Norway.*
Dec. 18, 1917: .....*France.*
Jan. 15, 1918: Dr. VOYSLAV M. YOVANOVITCH: *Serbia.*
Jan. 29, 1918: .....*Italy.*
Feb. 12, 1918: Dr. JOSEPH DUNN: *Scotland.*
Feb. 26, 1918: Dr. B. ISRAELI: *Russia.*
March 12, 1918: Mr. E. T. WILLIAMS: *The origin of China.*
March 26, 1918: .....*Holland.*
April 9, 1918: Dr. PAUL HAUPT: *Mesopotamia and Palestine.*
April 22, 1918: Annual meeting and election of officers.

Some, perhaps most, of these lectures will be illustrated by lantern slides or otherwise. The public will be welcome.

WM. H. BABCOCK,
*President.*

XU